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RE: New Patent Application
     GLOBAL ENCRYPTION SYSTEM
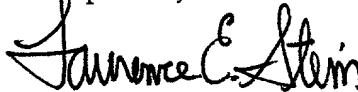   Attorney Docket No. 11382.100

Dear Sir:

Enclosed herewith is a new patent application consisting of 61 pages of specification, 5 claims, 1 of which is independent, 9 sheets of drawings and an Abstract.

This application is being submitted without a declaration and in accordance with 37 C.F.R. §§1.53 and 1.55 and without the filing fee.

Inventor: REECE, Richard W.
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The undersigned attorney states that he is authorized to file this application on behalf of the inventor.

Respectfully submitted,

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Enclosures

GLOBAL ENCRYPTION SYSTEM

ABSTRACT OF THE DISCLOSURE

5   A system and method for encryption, transmission and decryption of data based on a publicly or other wide area broadcast random number sequence. Encryption is by a selected subsequence from the broadcast random number sequence, the selection being at a sample time relative

10   to a synchronization event, with the sample time calculated based on a private key. Decryption uses the same private key to select the same subsequence from the broadcast random number sequence, as detection by the sender and receiver of the synchronization event and a

15   sampling time based on a commonly known private key allows the sampling to be synchronous. Alternative embodiments employ trusted agents if the sender and receiver do not have a common private key.

GLOBAL ENCRYPTION SYSTEM

DESCRIPTION

5 ### *Field of the Invention*

This invention relates generally to the field of data encryption and, more particularly, to a method and apparatus for encryption, transmission and decryption
10 utilizing a broadcast random data sequence accessible by the sender and receiver.

Description of the Related Art

15 In recent years, several papers and patents have disclosed advances in developing information-theoretically secure cryptosystems. Where possible, information-theoretically secure systems have substantial advantages over cryptosystems based on assumptions of an
20 adversary's processing power. Such computational systems include public key systems and some private key systems such as the Digital Encryption Standard (DES) and Advanced Encryption Standards (AES). One advantage of information-theoretically secure systems is security:
25 information-theoretically secure systems implicitly assume that an adversary has unlimited computing power, so such cryptosystems are generally regarded as having achieved the "unbreakable" status of a one-time pad. In contrast, cryptosystems that base their security on an
30 adversary's estimated processing power cannot achieve this status and so are less secure.

In most existing cryptosystems, the process of creating security, in terms of uncertainty about the plaintext, and the process of encryption, i.e., transferring that uncertainty to the plaintext, are

5   inseparable. In the current art of most private key and all public key systems, the message must exist before security can be created, and often the message itself is an input to the key. It is so common that it is unusual in the current art to suggest that the "encryption"

10   process may be broken into two separate conceptual operations, but it is crucial to do so in order to highlight the advantages of the present invention.

The structure of most information-theoretically secure systems has a distinct advantage that enables the

15   actual process of transforming the plaintext into an indecipherable ciphertext to take place at extremely high speed, usually with a bare minimum of processing power. This speed is achieved by separating the randomization process, the creation of the uncertainty that an

20   adversary will confront, from the process of transforming the plaintext into ciphertext. This separation is created when information-theoretically secure systems form the equivalent of a "one time pad" of random numbers that both users possess but about which the potential

25   adversary has no information. The actual encryption process is a simple XOR (modulo 2) operation that transfers the uncertainty of the random numbers to the message. The result is less time between message creation, encryption, and transmission.

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Message		XOR bit		Result
		(random bit stream)		
0	$\Rightarrow$	0	$\Rightarrow$	0
1	$\Rightarrow$	1	$\Rightarrow$	0
1	$\Rightarrow$	0	$\Rightarrow$	1
0	$\Rightarrow$	1	$\Rightarrow$	1

The vast majority of the costs, measured in terms of time, resources, and processing power, associated with the one time pad are correlated with the process of creating and distributing security, i.e., the uncertainty, and not the actual process of encrypting the plaintext message, e.g., the XOR operation. This suggests that the real costs of any encryption system are created by the production of uncertainty, or to use another word, randomness.

The one-time pad is the original information-theoretically secure cryptosystem and remains the foundation at the base of the more recent cryptosystems that achieve provably secure status. The one-time pad is the core cryptosystem proven to be unbreakable in theory (Claude Shannon, in the "Communication Theory of Secrecy Systems", *Bell System Technical Journal,* Volume 28, Oct. 1949, Pp. 656-715.), and it allows for rapid and unambiguous encipherment and decipherment. Its difficulties, however, are also well known, and these sharply limit its use to circumstances that require absolute secrecy and have few time or cost restrictions.

The main difficulty with the one-time pad resides in the broad category of key management. The key management problem may be broken into two components: key

distribution and actual key management by users. The latter component was a larger challenge in the years before the advent of massive amounts of cheap computer storage, when large quantities of random numbers had to

5   be printed on pads and controlled by the users. Since that time, the huge increase in computer memory capacity has mitigated the storage problems by allowing very large files of random numbers to be inexpensively stored for long periods of time and managed. Access to these pads

10   remains a strong security concern, but that is true of any cryptosystem. The remaining challenge is key distribution.

More specifically, in existing methods of key distribution, large "pads", which are now computer files,

15   of random numbers must be distributed ahead of time, through secure channels, to each individual who will communicate using this system. Very rapidly this task becomes a formidable obstacle, both in terms of maintaining secrecy and in the economic sense of

20   containing the costs.

Viewing the recent emergence of new cryptosystems that achieve the level of information-theoretically security, all have the common element of introducing a new mechanism for distributing a large random key that is

25   unknown to a potential adversary. This large random key is then used as a one-time pad, thus allowing the system to achieve perfect secrecy. Quantum cryptography for example, uses quantum spin to transfer random information between two users. A potential adversary has a low

30   probability of intercepting all of this information, and users can use this difference in information to build a one-time pad with a very high degree of confidence. A

further advantage of this system is that it does not require the prior exchange of a private secret key through a secure channel. Instead, it requires only an authenticated public channel where the two users can

5 assure the identity of the other user.

Other methods for creating and exploiting such information differences have been proposed. One of these methods is disclosed in U.S. Patent No. 5,161,244, referenced hereafter as "the '244 patent." The '244

10 patent describes an encryption system that can achieve information-theoretical levels of secrecy by exploiting a difference in information between individual users and an adversary. The '244 patent also teaches how information differences may be created by utilizing the expected

15 errors in a communication channel; two users may exploit the difference information created by this high error rate to achieve perfect secrecy-- even against an adversary who has a lower expected error rate than either user. One possible embodiment utilizes a satellite

20 broadcast of low power to create a common source of random numbers with an expected error rate in the broadcast that will differ with each potential receiver. Again, the users do not need to exchange a private secret key to achieve this level of security as long as their

25 public discussion is conducted through an authenticated public channel. In both of the above systems, the use of a (relatively) small private key exchanged via a trusted courier or some other means allows the requirement for an authenticated public channel to be relaxed.

30 Neither of these systems, however, has been implemented in a commercially viable system. Quantum cryptography has been experimentally demonstrated but,

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even if some of the technical limitations (range, for example) are overcome, both it and Maurer's proposed system have structural aspects that will drive up the economic cost of implementation. Further, with quantum cryptography, one user must send extensive quantum information directly and exclusively to the other user. This drives up the cost of implementation and limits the capability of the system to achieve economies of scale. Maurer's system, on the other hand, has the advantage of using a common broadcast of random numbers, allowing many users to simultaneously use the exact same broadcast and thus share the cost and achieve better economies of scale. However, Maurer's system still requires extensive and exclusive (one to one) communications between two users. The amount of communication required can be seen from the following: Actual implementation with current technology may require the communication of one megabit between the two users for every one random bit generated for use as the encrypting key (the "one time pad"). Even in this era of plentiful, cheap bandwidth, the ratio is staggering and will not scale well if millions of users attempt to use the system on a regular basis.

Another system has been proposed by Maurer and Christian Cachin, in a published paper on achieving information-theoretically perfect secrecy when an enemy is "memory bounded", titled Maurer and Cachin, "Unconditional Secrecy against Memory-Bounded Adversaries." *Proceedings of Crypto '97* (B. Kaliski, ed.), Lecture Notes in Computer Science, Springer, 1997.) In the paper, Maurer and Chachin propose that such unconditional secrecy could possibly be achieved by using a high bandwidth satellite channel with a *low* error rate

to broadcast a long but limited string of random numbers. When an adversary does not have sufficient memory to record the entire broadcast of random numbers, unconditional security for a message of limited length is possible, subject to certain specific parameters and assumptions.

The Maurer and Cachin proposal possibly resolves some of the drawbacks noted for quantum cryptography and the embodiments of U.S. patent 5,161,244. More particularly, the common broadcast allows universal access, suggesting that many users could use the same broadcast and thus reduce the cost of implementation. In addition, the larger the gap between the adversary's memory and the broadcast strong of random numbers the lower the amount of information that must be transferred between individual users.

The Cachin and Maurer paper, however, proposes a broadcast of random numbers that is limited in duration, and the time of this broadcast may well be known to the adversary. The limited structure of this broadcast clearly reduces the cost of broadcasting the random numbers by reducing the amount of time a satellite or some other high bandwidth communication system must be devoted to the cryptosystem. High bandwidth systems are extremely capital intensive to design and implement, so at first it appears that a limited broadcast represents the least expensive option and therefore has higher potential commercial viability.

The present inventor, however, has identified that the limited nature of the broadcast restricts its practical and economic use to a few users with considerable resources. The first basis for the

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restriction is that it is relatively expensive to implement a *limited* broadcast of random numbers because it restricts the number and size of messages and therefore the number of potential users. These few users and small quantity of messages must bear the high fixed costs of the satellite system, resulting in a system with high costs per user or per message. The second basis for the restriction is that any limited broadcast may be overcome by well-funded adversaries who know about the size and timing of the broadcasts. Memory may be re-used, so the adversary may spend a fixed amount of capital on memory (even if the number is quite high) and then amortize this cost over many messages. The third reason is that those users who require the greatest security typically face the best challenges from the most capable adversaries, so these users are less likely to use a limited broadcast. Unfortunately, these same users are also the parties most capable of paying for a high-cost system, so a limited broadcast system becomes even less economical because the market segment most able to pay will be the least likely to use it.

SUMMARY OF THE INVENTION

It is an objective of this invention to provide a system that, against many classes of enemies, will produce secrecy by placing them in a memory bounded condition. In the context of this objective, memory bounded is defined as a condition where the adversary does not have sufficient memory to record all or a very large percentage of the random number broadcast and, for

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that reason, it does not have complete information about a broadcast of random numbers.

It is a further object to allow low-cost implementation of high-quality security for a great many users, using relatively low amounts of processing power, in a broad variety of circumstances.

It is another objective of the present invention to provide economies of scale to users of the encryption system, and also impose substantial cost burdens even on enemies with considerable resources.

It is a further objective of the present invention to impose a constant stream of costs upon a potential adversary.

It is a further objective of the present invention to utilize the continuous nature of the random broadcast to its fullest possible extent by reducing or eliminating any information a potential adversary may have regarding the time at which the users exchange a private key.

It is a still further objective to conduct error correction, key update, and other public discussions that may be used to form a secure private key in a manner that limits the information an adversary may develop regarding the time at which the users are drawing random bits from the continuous broadcast.

One key aspect of the present invention is that it utilizes a continuous broadcast of random numbers, one that is ongoing in time. In a preferred embodiment, this broadcast will be carried through a global satellite system comprising multiple satellites that enable complete global coverage so that two users may access the same exact broadcast from virtually any geographic location. Another key aspect of the present invention is

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the use of a random number "reservoir" that is formed
from random bits downloaded from the random number
broadcast. This reservoir is used to provide the
encrypting key that converts the plaintext message into

5   ciphertext. It is an objective that the reservoir is
replenished independently of the messages exchanged
between users. A feature of this invention is that this
reservoir can be used as a buffer, in optional
embodiments, which will reduce or eliminate any

10   information a potential adversary may have regarding the
time at which the two users sampled the broadcast of
random data.

It is an objective of the present invention to
utilize the continuous broadcast structure to utilize a

15   new type of uncertainty not utilized in previous
proposals for unconditionally secret systems. In the
system disclosed here, the continuous broadcast enables
the time of the user's key exchange to become an inherent
part of the private key itself. An adversary of two

20   users in a continuous broadcast system who has no
information regarding the time of the private key
exchange will face a condition of either greater
uncertainty or greater costs for additional memory. Even
extraordinarily well funded adversaries must contemplate

25   identifying the time of the private key exchange in order
to increase the probability of obtaining useful
information about the users' encrypting keys, or reducing
their memory and search costs. This suggests that an
adversary must have interception capabilities not

30   contemplated by Maurer, Claude Shannon, or most
practitioners of the current art. More specifically, the
adversary must be able to identify when a private key

exchange took place; this requires observation or interception capabilities not normally assumed in the design of cryptosystems.

In addition, the present invention teaches that
5   continuous operation and a random number reservoir are not just improvements in encryption capability, but are economic improvements as well, making the system accessible and usable by a much larger body of users. Any users, irrespective of their geographic locations,
10   may draw from the random broadcast anytime, anywhere. This allows more users to share in the cost of the system, thus allowing users—rather than just well-funded adversaries—to achieve economies of scale and amortize high costs across a very large number of messages. This
15   is a substantial advance over the current art.

Finally, the present invention imposes steadily rising storage costs on a potential enemy. As time passes, the present invention gains strength and reduces costs for users, while an enemy faces continually rising
20   challenges on its resources. Such an advance generates a powerful advantage in the art of cryptography.

BRIEF DESCRIPTION OF THE DRAWINGS

25   The foregoing and other objects, aspects, and advantages will be better understood from the following description of preferred embodiments of the invention with reference to the drawings, in which

Fig. 1 is a system diagram of an example embodiment
30   according to the present invention;

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Fig. 2 is a hardware architectural block diagram of a typical example individual user's computing system within the system of Fig. 1;

Fig. 3 is a flow chart showing an example general
5   method according to the present invention;

Fig. 4 is a flow chart depicting an example method of a transfer of private key, via trusted agent, within the method of Fig. 2;

Fig. 5 is a flow chart depicting an example of a
10   trusted agent handling a private key generation request within the method of Fig. 2;

Fig. 6 is a flow chart depicting an example alternative method to that of Fig. 4 for transferring a key via trusted agent;

15   Fig. 7 is a flow chart showing an example method of using two trusted agents for securing a private key within the method of Fig. 2;

Fig. 8 is a flow chart showing an example method of generating private key when there is only one trusted
20   agent in common between two users; and

Fig. 9 depicts an example private key exchange between two users having respective trusted agents.

DETAILED DESCRIPTION OF THE INVENTION

25   <u>Definitions of Terms</u>

The following definitions govern this description, unless otherwise clear from the specific context in which the terms are used, or where a different or additional definition is stated:

Ciphertext, *C*:

Ciphertext is a standard term of art referring to the plaintext after it has been encrypted to form the ciphertext.

5

Encrypting Key, *E*

The encrypting key *E* represents a block or string of random bits drawn from the reservoir *RNR* that are XORed with the plaintext to form the ciphertext. For perfect

10 secrecy, there must be a unique corresponding bit drawn from the *RNR* for every bit in the plaintext of the message.

Private Key, *k*:

15 The private key k contains *n* number of bits. The key k is a secure private key that is exchanged between any two or more individuals. The private key *k* is usually exchanged via a "trusted courier" or through a secret channel so that no information about the value of the key

20 is revealed to a potential adversary. A separate *k* must be exchanged between each set of individuals who wish to conduct secret communications. The private key *k* must be sufficiently large to "point" to all the possible bits that will be broadcast during a time, *t*. As described, a

long k may be broken into several sub keys that point to different bits within the same time t. These sub keys could significantly increase the security of the encryption system. One consideration is that a very high speed random number broadcast operating at 1 gigabit a second will generate approximately 2^{55} bits in a year, so a key of 55 bits is sufficient to uniquely point to a single bit in a year's broadcast. A longer k of 110 bits could be used to uniquely identify two bits within that same year. Alternatively, three sub keys of 36 bits could be used to identify 3 bits within a shorter span of time, and so on.

In the current art, the secrecy of a private key is assumed to cover only the content: that is, the enemy does not know the value of the specific bits in the key. In the present invention, it is highly advantageous if the time of the transfer of this private key is also secret. In an ideal embodiment, a potential adversary will have zero information on the time of any private secret keys exchanged between two users.

In the current art of public and private keys systems, such information is either predetermined, assumed to be known by the enemy, or not relevant. But it is a significant advantage of the present invention

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that this time may become a vital inherent part of the key itself, and may add a very considerable amount of uncertainty to an adversary's attack without any additional processing, expenditure, or resources consumed

5   on the part of the users of this system. This represents a considerable advantage over the present art.

Random Data Stream (*RDS*)

The continuous stream of random bits to be received

10 by the parties using the present invention to encrypt their communications.

Sample (*SMP₁*, *SMP₂*, *SMP₃*, . . .*SMPₓ*) ; size in bits (*s*)

A series of blocks (or strings) of random bits

15 downloaded or "sampled" from the *RDS*. The timing of these samples is derived by algorithm(s) *z* from the private key *k*. The *number* of bits in *SMP* is denoted by *s*. The number *s* may be predetermined and assumed known by an enemy or derived from the private key, *k*, and unknown by the

20 enemy.

Random Number Reservoir ($RNR_1, RNR_2, RNR_3, RNR_4, . . . RNR_i$)

The RNR is a file of r bits or set of files on the storage device of the users' computers, as described further below. Each RNR contains a series of the samples

5 (SMP_I) defined above, which are selected by algorithm z over time from the RDS. A separate RNR_n is required for each contact with whom the user wishes to communicate in secrecy. For example, if Alice wishes to communicate in private with Bob and Charlie, but individually, so that

10 neither Bob nor Charlie can read Alice's messages to the other, then Alice must maintain two reservoirs, one for Bob and one for Charlie. A third reservoir would be required to provide encryption for common communications between all three.

15 This is part of the traditional key management problem typically associated with private key systems. The present invention reduces this problem's significance through reservoir replenishment, which allows smaller reservoirs. In an ideal embodiment, an adversary will

20 have zero information about time at which this reservoir is replenished.

In order to achieve perfect secrecy, a potential adversary must have either zero information or an arbitrarily low probability of having any information on

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the contents of the *RNR*. In a preferred embodiment, the
users will have undertaken processes and methods that
have reduced or eliminated any information a potential
adversary may have had regarding the time at which the
5   *SMPs* were drawn from the *RDS*. Those skilled in the art
will appreciate that the reservoir may be constructed in
many ways from an s string of randomly drawn *SMPs*. In
preferred embodiments, these *SMPs* will be integrated into
the reservoir (XORed or added modulo 2) successively so
10 that at any point in time the bits in the reservoir
represent a summation of all previous *SMPs*. In other
words, the state of the bits in the reservoir will, in
preferred embodiments, always be influenced by the states
of all previous inputs.

15   The encrypting keys, *E*, will be drawn from the *RNR*.

    The initial size, in bits, of the *RNR* is *r*. This *r*
may be predetermined in a public discussion accessible by
a potential adversary, or derived from *k*.

20 **Plaintext (*P*)**

    The term "plaintext", referenced herein as "P", is
standard term of art. In the present disclosure, the
term is generally used to describe a message at a
specific point in the encryption process: when the

message has been converted from the natural language by some coding mechanism to a string of bits that will be encrypted.

Selection algorithm (z)

Selection algorithm (z) represents an algorithm or set of algorithms designed to take the private key k and generate a set of instructions for the operation of the encrypting process. One of the key variables is time t.

Time (t)

The time at which the user's computing device will collect a sample *SMP* from the *RDS* for storage in the *RNR*.

Trusted Intermediary or Trusted Agent

An individual with whom a user has exchanged a private key in the past and now maintains a current, synchronized *RNR* so that the user and the trusted agent may conduct secret communications.

FIRST EXAMPLE SYSTEM EMBODIMENT

Referring to Figs. 1 and 2, a first example embodiment of a system of this invention will be described. Fig. 1 shows an example high level system architecture, with Fig. 2 showing a more detailed architecture of typical example of the Fig. 1 User

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Computing System 108n. Fig. 3 described is an example a general encryption method of this invention performed, for example, by the system of Figs. 1 and 2.

As will be clearly seen by one of ordinary skill in
5   the art upon reading the present disclosure, the particular architecture and related hardware selection and arrangement depicted by Fig. 1 is for purposes of example only and is by no means limitative. The gist and novelty of this invention does not exist in the specific
10   selection of hardware and arrangement thereof depicted by Fig. 1. Other example system architectures, combining and/or omitting hardware shown in Fig. 1, or using substitute methods of performing functions within the system, are contemplated.

15   The example system architecture of Fig. 1 comprises a Random Number Generator 100 which generates a Random Number Sequence *RNS* that is transmitted to a Broadcast System 102. The Broadcast System 102 for the basic embodiment of Fig. 1 distributes, or broadcasts, the *RNS*
20   to the Ground Station 104 and to a plurality of User Computing Systems 108n and to a plurality of corporate mainframe computers 116n. The basic example embodiment of Fig. 1 depicts three User Computing Systems, labeled as 108a, 108b, and 108n. The units 108a and 108b are
25   particular ones of the units 106n used for purposes of describing example methods of this invention and are referenced herein as the First User Computing System and the Second User Computing System, respectively.

The Random Number Generator 100 is preferably a true
30   random number source derived, for example, from a natural source such as radioactive decay or background radiation noise, generates a continuous stream of random numbers

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(random bits) that is unpredictable and uniformly distributed. As known to those skilled in the art, the higher the rate of this stream of random numbers, the more advantageous the versatility, security, and cost

5   benefits of entire cryptosystem. Rates of several gigabytes per second or greater are contemplated. As stated, the output of the Random Number Generator 100 is a random data stream, referenced hereinafter as *RDS*.

       The distribution of the *RDS* to the User Computing

10   Systems 108n is shown in Fig. 1 as being via downlink from the Broadcast Satellite 106. Pursuant to this depicted *RDS* distribution the Broadcast System 102 transmits the *RDS* to a Ground Station 104 which uplinks to the Broadcast Satellite 106. As can be seen, the

15   embodiment of Fig. 1 is preferred for many applications as Ground Station 104 delivers the *RDS* to the Broadcast Satellite 106 so that the satellites function as "bent pipes," receiving the *RDS* from the ground station and retransmitting it across a wide geographical area. This

20   method offers several advantages: less equipment in orbit, access to 100 for repair purposes, and simpler methods to transfer the *RDS* to multiple satellites.

       The Broadcast System 102 will continuously broadcast the *RDS*. This Broadcast System 102 must be capable of

25   delivering very high data rates with very low error probabilities. In addition, the Broadcast System 102 must have sufficient coverage through, for example the Ground Station 104 and Broadcast Satellite 106, so that any two users, e.g., the First Computing System 108a and

30   the Second User Computing System 108b, will receive the broadcast *RDS*.

The medium by which the Broadcast System 102 transmits the *RDS* to destinations such as, for example, the Ground Station 104 and User Computing Systems 108n, may be wireless radio, satellite, or high capacity

5   wireline, such as coaxial cable or fiber optic line. Fig. 1 shows each User Computing System connected to the Broadcast System by way of satellite receiving dish 110 and via the Internet 114.

The chief drawback of a wire or fiber-based

10 broadcast system is that its reach is not ubiquitous. Where mobility is not an issue, and where access to the lines is assured for both parties, then a fiber optic line will have substantial advantages because of its extraordinary capacity.

15 This disclosure primarily describes an embodiment using a high capacity satellite system such as the Ground Station 104 and Broadcast Satellite 106 of Fig. 1. However, this described example is not intended to limit the scope of the present invention to satellite broadcast

20 systems. In addition, Fig. 1 shows a single Broadcast Satellite 106. In practice a satellite broadcast system may contain one or more satellites in different orbits, and in a preferred embodiment will have a sufficient number of satellites to achieve global coverage. In

25 military embodiments, additional satellites may be used to counteract jamming by an enemy, a known practice utilized by the Global Positioning System (GPS).

Each of the example User Computer Systems 108n includes a Satellite Receiving Dish 110n. A Trusted

30 Courier or Secret Channel 112, represented in Fig. 1 as a human form, transports information to or between User Computing Systems 108n, including the First User

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Computing System 108a and the Second User Computing
System 108b, as will be described below. The Trusted
Courier or Secret Channel 112 is a means by which two
individual uses are able to exchange a private key. In

5   addition to the content of key itself remaining private,
in a preferred embodiment, the method and timing of the
key delivery will also be secret.

As stated previously, the particular architecture
and related hardware selection and arrangement depicted

10   by Fig. 1 is only to facilitate a description of the
invention and is for purposes of example only. Many
variations in arrangements of the hardware, and the site
where functions are performed are contemplated by this
invention. For example, random number source 100 may be

15   incorporated directly into the same satellite 106 used to
broadcast the *RDS*, but this may be advantageous only for
single satellite embodiments. Further, error correction
and synchronization bits or schemes may be included in
the generated RDS. More particularly:

20   <u>Error Correction</u>

Additional bits or "packets" (blocks of bits)
inserted into the *RDS* for the purposes of error
correction and synchronization. Such "deterministic" or
predictable bits will reduce the overall rate of random

25   bits, but in most embodiments their addition will be
advantageous to end users. Error correction codes are
well known in the art of information theory and
communications.

<u>Synchronization</u>

30   Synchronization techniques are also well known. In
this system, as data rates increase, the accuracy of
synchronization between two remote and unconnected

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individuals must also increase. Inserting
synchronization bits directly into the *RDS* allows less
accurate and less expensive clocks in user devices.

Fig. 2 shows a hardware architecture of a typical
5   example User Computing System 108n within the Fig. 1
system. The Fig. 2 example architecture comprises a
common bus 1000, a microprocessor 1002 connected to the
common bus, a random access memory RAM 1004, clock 1006
and read only memory ROM 1008 connected to the processor.
10   Also connected to the common bus 1000 is a keyboard or
other input device 1010, and a long term data storage
1012, and a removable data storage 1014, such as a CD
ROM, ZIP drive or the like. The Fig. 2 example User
Computing System 108n further comprises a satellite
15   receiver or fiber optic line 1016 and a modem 1018. In
the Fig. 1 example the satellite receiver or fiberoptic
line 1016 would be a satellite receiver connecting to the
depicted satellite dish 110n associated with each User
Computing System 106n. The modem 1018 of the Fig. 2
20   example User Computing System 106n connects, in the
example system of Fig. 1, to the Internet 114.

It is an advantage of the present invention that
many devices of varying processing capability may be
used. Therefore, although a typical embodiment is
25   represented by a conventional personal computer with a
satellite downlink receiver, 108n is better defined by
its function than by its specific hardware. In view of
this, the general requirements of the User Computing
System 108n are enumerated as (a) through (f) as follows:
30

a. Means for Receiving the Private Key and
   Other Data Input:

The User Computing System 108n must be able to
receive input of a key k of varying length. Typically
5   the input will come from a keyboard, such as item 1010 of
the Fig. 2 example, or from a mobile storage medium such
as a floppy disk or CD, such as item 1014 of Fig. 2.

b. Means for Receiving and Processing Recovered
10   RDS Bits Output from Satellite Receiver/Modem:

The User Computing System 108n must have a
microprocessor able to receive and perform calculations
utilizing data supplied by the *RDS*.

15   c. Means for Data Computing and Processing:

The example User Computing System of Fig. 2 has a
microprocessor 1002. Regarding performance requirements,
it is an objective and advantage of the present invention
to require little processing power so that a wide range
20   of processors may be used. Therefore, general
microprocessors found in most present day personal
computers, such as, for example, the Pentium™ II,
Pentium™ III, or PowerPC™ chip, as well as
microprocessors found in many other digital devices, such
25   as a Palm Pilot™, will typically have sufficient
processing power for most embodiments of the present
invention.

d. Data Storage Device and Storage Medium:

30   The User Computing System 108n must have the
capability to store segments of the *RDS* data. The means
for such storage covers a wide number of potential

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devices, including hard drives, floppy drives, "Zip" drives, flash memory, tape systems and optical drives such as CD or DVD systems. Most hard drives in PCs or non-volatile storage in mobile devices will be

5   sufficient. Storage requirements for the present invention will be correlated with the total size in bits of the messages communicated by the individual user per unit of time. In general, frequent communications will require more capacity while occasional communications

10   will require less. Users whose computing systems are in an insecure area may prefer a removable medium, such as a floppy disk or recordable CD The example User Computing System 108n of Fig. 2 has a long term data storage 1012, and a removable data storage 1014 which serve this

15   function.

      e.   Clock: (optional for some embodiments)
          Clocks, such as the clock 1006 of Fig. 2, may be used to synchronize the operation of individual users.

20   As will be understood from this description, individuals using this invention's encryption system to communicate must be synchronized so that they are both receiving and downloading the RDS broadcasts at the same time, thus acquiring the same string of random numbers. The

25   synchronization process need not be kept secret, but it must have no correlation whatsoever to the encryption time or procedures. Highly accurate internal clocks are preferred; those found in conventional commercially available personal computing devices will likely be

30   sufficiently accurate for most embodiments. It is an objective to use such systems without modification, so

the inclusion of synchronization bits in the *RDS* will be advantageous.

    f.   Satellite Receiver, Modem or Other Landline
5   <u>Receiver</u>:

    The User Computing System 108n must, for this general embodiment, be capable of receiving the *RDS* broadcasts from the Broadcast Satellite 106 or Internet 114, and downloading the *RDS* to the computing resources
10 of the User Computing System 108n. An embodiment utilizing a satellite broadcast system will utilize an antenna or dish, such as the antenna 110n of Fig. 1, optimized for the satellite and frequency. Receivers for wireline systems will be modems, such as the modem 1018
15 of Fig. 2, capable of translating the broadcast methods back into a stream of random bits.

FIRST EXAMPLE METHOD OF THE INVENTION

20   Referring to Figs. 1-3, an example of the present inventive method and an example system for performing the same will now be described. The block flow diagram of Fig. 3 is for purposes of describing, to one of ordinary skill, this invention and its operation. Actual
25 implementations of this invention which are covered by the appended claims may omit one or more steps of Fig. 3, or may combine two or more method steps depicted in the figure as separate into a single step, or perform the steps in an order different from that which is depicted.
30   The method of the present invention, as described in reference to the example of Fig. 3, consists of three related sub-processes. The first is the local generation

and maintenance at each of the First User Computer 108a and Second User Computer 108b of Random Number Reservoir *RNR* for encryption and decryption of data. Steps 200 through 230 depict an example embodiment of this process.

5   Fig. 2 steps 240 through 258 depict an example creation of plaintext and encryption of the plaintext using the *RNR* generated and maintained at a sender's computer, such as the First User Computer 108a, by that computer carrying out steps 200 through 230. Fig. 2 steps 260

10 through 270 depict an example reception and decryption at a receiving party's computer, such as the Second User Computer 108b, of the encrypted data generated by steps 240 through 258. The extracted bits from the *RNR* used for encryption and decryption are identical. Therefore, for

15 purposes of this description, it is assumed that the *RNR* generation process of steps 200 through 230 are performed identically as between the First User Computer 108a and the Second User Computer 108b. Accordingly, for ease of description, the First User Computer 108a and the Second

20 User Computer 108b are referenced as User Computing Device 108 when both 108a and 108b, for the particular, are performing the same steps locally. Similarly, the First Satellite Dish 106a shown in Fig. 1 as connected to the First User Computer 108a, and the Second Satellite

25 Dish 106b shown as connected to the Second User Computer 108b are referenced collectively as Satellite Dish 106.

Steps 200 through 230 of the example method of Fig. 2 are performed while a continuous stream of random numbers, represented as bits in this present disclosure),

30 the *RDS* is generated by a true random number source 100 at extremely high data rates.

27

In a preferred embodiment, the *RDS* is continuously broadcast (24 hrs/day) over a wide geographical area on a predetermined frequency using a communication system such as the Ground Station 104 and Broadcast Satellite 106 of

5 Fig. 1, preferably with an extremely low error rate. Those skilled in the art will appreciate that this "continuous" broadcast may not need to operate 24 hours a day to achieve many of the same benefits disclosed here. For example, the broadcast may take place for a limited

10 number of hours, perhaps during periods of time when demand for bandwidth is low, thus reducing costs. This limited broadcast of random numbers may take place on a periodic basis, and so, over the course of time, will also form a very large stream of random numbers, the *RDS*.

15 Also, in a preferred embodiment, the commencement of this *RDS* broadcast will be unknown to any potential adversary. Although the broadcast itself will clearly form a public revelation of its own existence, in a preferred embodiment a potential adversary will not

20 become aware of the broadcast until after it has started. Further, it will be even more advantageous if the users were aware of this broadcast before their potential adversary. These are not necessary or limiting conditions, but merely extra potential advantages for

25 potential users that may be utilized to increase their potential security against a memory bounded adversary.

Referring to Fig. 2, the method will be described by an example communication between two users, Alice and Bob. Alice uses the First User Computer 108a and Bob uses

30 the Second User Computer 108b. For this example both Alice and Bob receive the same *RDS* broadcast, and both have the same operating software.

28

A.   Private Key Exchange and *RNR* Generation

Referring to Fig. 2, first at step 200 Alice sends
Bob a private key, k. A usual method is via a trusted
courier. In a strongly preferred embodiment, the time of
5   the key exchange itself is secret so that potential
adversaries have zero knowledge about the time of the key
exchange. If the time of the key exchange remains
secret, the users of this system will have imposed either
additional cost or uncertainty, or both upon a potential
10   adversary. Such extra uncertainty represents an advance
over the prior art, as it may force an adversary to
perform work before two users have even decided to
conduct secret communications with this system.

Next, at Step 202, both Alice and Bob input the
15   Private Key k, either through the keyboard, some other
manual input device, or a removable storage medium such
as a floppy disk. In response, Algorithm z, which is
public knowledge and is common to Bob and Alice, will
transform k into a set of parameters and instructions
20   that will control the operation of the encryption
process. Upon reading the present disclosure Algorithm z
can be readily written by one of ordinary skill in the
art.

The most crucial variable that k (or a sub key) and
25   z will determine is the time t when the First User
Computer 108a and Second User Computer 108b, referenced
collectively as User Computer 108, will sample the *RDS*.
That sampling is described below in reference to other
steps of Fig. 2. This time t is determined by k and z
30   and stored in non-volatile memory so that its value will
be retained. This determination of t is as follows:
Periodically, at a cycle time determined by the check

clock operation of step 204, the User Computer 108 (First
User Computer 108a and/or Second User Computer 108b) will
compare, at step 206, the value of t with the current
time in the clock. When the difference in the values is
sufficiently small, the process goes to step 210, wherein
the microprocessor (not shown) in the User Computer 108
begins receiving and analyzing the *RDS*, through an
interface (not shown) between it and its Receiving Dish
106. The interface (not shown) includes radio signal
receiver, downconverter and Analog to Digital Converter,
and such devices are well known in the art.

Next, at step 212 the User Computer 108 reconstructs
the RDS from the sampled data. If synchronization bits
are included in the *RDS*, step 212 includes a
microprocessor step (not numbered) of seeking to match
the values from the synchronization bits in the *RDS* to
the value of t.

As shown by step 214, at time t the User Computer
108, via its Receiving Dish 106 and interface will
"sample" the *RDS* broadcast for a limited amount of time
to create a block of random bits, *SMP*. As those skilled
in the art will appreciate, it may be advantageous for
the system to begin downloading the *RDS* to a temporary
file before time t in order to insure that the entire
sample starting at time t is recorded. The extra bits
preceding t may be discarded to create the *SMP*.

The timing of Fig. 2 steps 204 through 214 is
independent of the start and stop times of the data
packets (not shown), if used, of the received bit stream
from which the RDS is recovered. More particularly,
although the broadcast system, e.g., the Broadcast System
102, Ground Station 104 and Broadcast Satellite 106, may

transmit the *RDS* in the form of data packets, or blocks
of bits, for error correction purposes, the formation of
the packets will not affect how the *SMPs* are started and
formed. The packets should be a communications vehicle

5   only; the packet structure should not affect the process
for identifying time t and the formation of the *SMPs* for
the *RNR*. If the broadcast system does indeed break the
RDS into a series of packets, these packets should be
regarded simply as temporary groupings designed to

10   facilitate transport. After receipt of the broadcast,
the various packets should be aligned together
sequentially in time to reform the original *RDS* for that
period of time. The *SMPs* are then derived from the
reconstituted continuous *RDS*.

15   Referring to Fig. 2, step 214 finishes, for this
example, by downloading the *SMP* to the appropriate Random
Number Reservoir *RNR* in the storage of the User Computer
108. The term "appropriate" is used because it is
contemplated that the User Computer 108 can maintain a

20   plurality of Random Number Reservoirs, *RNR*, each
associated with a particular party in communication and
its particular private key *k*.

Next, the process goes to step 224 where the
arriving *SMP* may be XORed with all of the current bits

25   that form the string of random bits already in the *RNR* to
create an entirely new *RNR*. Such an XOR operation will
require little processing power, but will add
substantially to the security of the overall system by
making it difficult for even an unbounded memory

30   adversary to derive the underlying *RNR*. Those skilled in
the art will appreciate that there are variety of methods
for XORing or integrating the recent *SMP* into the *RNR*,

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with varying degrees of protection created by each
potential method. Such persons skilled in the art will
also note that creating dependence on the previous state
of the *RNR* for the future values of the *RNR*, while an

5   enhancement to security, creates the risk of error
propagation. It also requires processing time, although,
it is important to note, the processing may precede the
actual encryption operation so that the time required to
actually encrypt the plaintext is the same basic XOR

10 operation.

Although not depicted in Fig. 2, the *SMP* may be
stored in a temporary file (not shown) before it is
integrated into the *RNR* that will eventually serve as the
private encryption/decryption key. This temporary file

15 will serve as a buffer, and packets of various sizes may
be derived from this temporary file for the purposes of
error checking. Those skilled in the art will recognize
how bit error checking procedures may be applied through
an authenticated public channel; some bits will need to

20 be discarded in order to reduce information leaked to a
potential adversary. It is also possible that bits from
the final *RNR* may also serve to authenticate the error
checking procedure so that the requirement for an
authenticated public channel may be relaxed. In an ideal

25 embodiment, the packets being checked for error will have
no correlation in time with their download from the RDS,
or with the order in which they were received.

Referring to the example of Fig. 2, at step 224 the
recovered *SMP* is XORed with the existing bits in *RNR*.

30 Next, step 226 checks if the *RNR* if full. If step 226
determines that the number of the *RNR* isn't full the *SMP*
is not discarded but its bits are now added, at step 228,

to the *RNR* so that the total number of bits in the *RNR* is increased. For the depicted example, if the *RNR* is full the SMP is discarded at step 230.

5   This process may be repeated at random intervals until the *RNR* is completed. After it is "full," the system can either continue to create new *SMPs* and XOR these through *RNR*, or in an alternative embodiment, the *SMP* may be discarded without being integrated into the *RNR*. New SMPs are created by steps 216, 218, 220, and

10   222, described below. In any of these embodiments, it is crucial that the depletion of the *RNR* through use will not trigger the system to replenish the *RNR*. The trigger to add bits to the *RNR* must be statistically independent from the use of the *RNR*, or a capable adversary may be

15   able to begin to guess when the system is sampling the *RDS* (*e.g.* right after an encrypted message is sent.)

       Referring to Fig. 2, if the system continues to create new SMPs the process is as follow: First, at step 216 the previous SMP is XORed into k to create k_1. Step

20   218 checks a counter (not shown) and step 220 compares the counter value to a predetermined value set in software to a value determined b k. If the comparison has a "No" value the process goes to step 222, advances the counter, returns to step 202, puts the new k_1 into

25   the Function (z) to generate a new sample time *t*, and repeats the process described above to obtain another SMP.

       There are a vast number of ways that the new *SMP* may be merged with the old key, but the point of the exercise

30   is to add new random bits to *k*. This new k_2 is run through *z* again to create a new time $t_1$and another *SMP* for the *RNR,* as described above.

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Those skilled in the art will appreciate that this entire process may be repeated for each sub key, (if the original key *k* was broken into sub keys) so that a two dimensional array is formed, where each sub key creates

5 its own *RNR* (or string of random numbers). These *RNRs* may be added together modulo 2 (XOR) to form a new string of random numbers. This latter method of utilizing sub keys would allow a user to increase security while holding *t* constant; it does, however, increase the size

10 of the private key *k* that must be exchanged.

Referring to Fig. 2, it is seen that by carrying out steps 200 through 230 on their respective computers 108a and 108b Alice and Bob have used the private key *k* and the commonly received *RDS* to create the exact same *RNR*.

15 Both computers 108a and 108b are synchronized in time, so they have sampled the *RDS* broadcast at the exact same instant, for exactly the same amount of time, and acquired the exact same random bits SMP when each performs step 214.

20 The reception of the *RDS* is passive, so an enemy will have no idea when Alice and Bob are sampling the *RDS*. Where the volume of bits broadcast through the *RDS* is very high, it is likely that an adversary will become memory-bounded—unable to record the entire *RDS*. Over

25 time it will be unlikely that even a well-funded adversary will have in memory a record of the *RDS* that contains useful information on what Bob and Alice have used for their *RNR*.

B.   Encrypting a Message.

30 Referring further to Fig. 2, encrypting a message is straightforward. Assuming that Alice is encrypting and sending a message for the First User Computer 108a, the

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first step at that computer is step 240 of creating the plaintext P. Next, at step 242 the First User Computer 108a determines if it has an *RNR* for transmitting messages to the particular Second User Computer 108b. If

5   it does not then it returns to the above-described step 200, exchanges keys with Bob and, by steps 202 through 230, generates the required *RNR*. If the answer at step 242 is "Yes" the First User Computer 108a executes steps 244 through 248 to determine whether or not it has

10 sufficient bits in its Random Number Reservoir *RNR* to encrypt the message P. Basically, to encrypt the plaintext message P, the number of bits in the *RNR* must be greater than or equal to the number of bits in P. If step 248 of the sending computer, i.e., Alice's First

15 User Computer 108a, determines that there are not enough bits in *RNR* then the process goes to step 250 and waits while steps 202 through 230 add to that computer's *RNR*. Once a sufficient number of random bits are in the *RNR* (equal to the number of bits in the plaintext message)

20 the process goes to step 252 described below. If step 248 determines that there enough bits in the *RNR* then the process goes to step 252 and extracts from the *RNR* the same number of bits as there are in P. Next, at step 254 the extracted bits from the *RNR* are XORed with the

25 plaintext message P in a one-to-one correspondence or ratio to create a ciphertext C. Then, at step 256, the ciphertext C is sent to the target contact, which, in this example, is Bob on the Second User Computer 108b. The extracted bits from the *RNR* are then discarded, as

30 shown by step 258. It must be noted, in reference to step 254, that each bit in the plaintext P must be XORed with a unique bit from *RNR*.

In addition, although not depicted in Fig. 2, additional random bits from the *RNR* may be tacked into the message to further hinder a potential adversary.

5 ## C.   Decrypting a Message

Referring to Fig. 2, Bob decrypts the received message C at the Second User Computer 106b by performing basically the same steps described for Alice at the First User Computer 108a. First, at step 260 Bob (on the
10 Second User Computer 108b) receives the ciphertext C. Next, at step 262 Bob's computer determines whether it has the appropriate RNR for decrypting a message from Alice. This is similar to step 242 performed by Alice's computer 108a. If the answer is "No" then Bob's computer
15 goes to step 200 to obtain the required RNR. If the answer is "Yes" then Bob's computer 108b at step 264 determines the length of the encrypted message C and then, at step 266, removes the exact same number of random bits from his reservoir RNR. Because Alice and
20 Bob have synchronized random number reservoirs RNR, Bob's random bits are exactly the same random bits that Alice used to encrypt the message. Then, at step 268 Bob decrypts by XORing this string of random bits with the encrypted message C to reveal the original message P.
25 Finally, at step 270 the bits extracted from Bob's RNR for performing the step 268 decryption are discarded.

Creation of an RNR through public discussion

30 Those skilled in the art will readily appreciate that this system may be used to apply lessons from quantum cryptography and other information-theoretically

secure systems to create an *RNR* exclusively through a
public discussion over an authenticated channel.
Briefly, the two users Alice and Bob agree that they want
to form a private key through a public discussion. They

5 may publicly agree on the perceived quantity of memory
possessed by their potential adversaries. In a preferred
embodiment, this will be sufficient as the rest of the
parameters should be standardized and thus will not
require further discussion. Although a potential

10 adversary will clearly have precise information about
when the two users have started to form a mutual *RNR*, the
continuous *RDS* broadcast still offers considerable
advantages in that it can create a condition where an
adversary must continually add memory resources or face a

15 decreasing probability of being able to gain useful
information from Alice and Bob's public discussions.

In a general form, both Alice and Bob will sample
the *RDS* at random intervals, and will record both the
time of the sample and the value of the bit(s) at that

20 time. Eventually, after a minimum amount of time
determined by their mutual agreement regarding the
probable size of an adversary's memory, Alice will begin
to send Bob through an authenticated public channel the
times at which she sampled the *RDS*. In a preferred

25 embodiment, this public discussion will take place
continuously over time rather than all at once. In
addition, it may be advantageous in some instances if the
times that Alice selects and sends will be selected at
random and will not be in sequential order. The

30 objective is to force an adversary into a condition where
it must continue to add memory capacity or face a
decreasing probability of obtaining useful information.

Alternatively, Alice and Bob may agree to randomly select and record a string of n bits. Alice selects n-x bits from this string and sends this information to Bob through the authenticated public channel. The n-x bits

5 substitute as the index marker, taking the place of the time as an index. If n-x is sufficiently large, there should be little probability of a collision, and there should be a unique n-x with a high probability. Bob searches his stored values for the specific sequence of

10 bits represented by n-x. Once found, Bob signals confirmation to Alice and both discard n-x and retain x for use in building the *RNR*. In both processes, subsequent actions to check for errors and apply privacy amplification where necessary are well known in the art.

15

FURTHER FEATURES AND EMBODIMENTS

20 The purpose of the following disclosure is not to limit the scope of the present invention but rather to clarify understanding and illuminate the versatility of the present invention. Future embodiments may utilize any of the following additional methods, or some

25 combination. The scope of the patent extends to virtually any algorithm operating within the framework of the above methods, where a continuous *RDS* and reservoir are used to form encrypting keys.

30

Private Key Length Variability

The private key k may be variable in size. Public
and private key encryption systems in the present art
5 generally utilize keys that have a precisely known number
of bits. This allows the software and hardware to be
custom-designed in order to increase the speed of the
encrypting process and provide a solid means for
ascertaining the potential work that must be performed by
10 the enemy.

This present invention does not need to utilize a
standard or universal sized key to achieve high-speed
encryption. Indeed, there may be, in certain
circumstances, advantages to using variable sized keys.
15 If the enemy faces a situation where a longer key is
probable, smaller keys may be exchanged and used to
create perfect secrecy for messages longer than k. This
uncertainty must be used carefully— the probability
distribution for the key size must be skewed strongly
20 towards the longer keys—so that each key within the total
set of possible keys is equally probable.

Key Transfer

In ideal embodiments, the time and method of the
25 private key transfer will also be secret. This will add
substantial secrecy, even against highly capable enemies
with unbounded memory. In order to counter this advance,
an enemy must develop new capabilities not contemplated
by Shannon, Maurer or others in the current art. Even an
30 unbounded-memory enemy must observe or gain knowledge of
the timing of the private key transfer or it will likely

confront a system that is unbreakable in practice (though not in theory except under very limited conditions.)

Private key *k* transfer

5   In a simple embodiment, *k* may be generated by a continuously broadcast radio signal that is received by both users, Bob and Alice, but is undetected, or not recognized by the enemy. The termination of the signal or a particularly long pause identifies the common start

10   time that will serve as *k*. Thus *k* could be as short as a single bit.

Synchronization of clocks

Many synchronization methods are contemplated; these

15   are three examples known in the current art:

*   Synchronization Method One

Individual users synchronize clocks or operations by connecting to each other directly or by exchanging data over the Internet.

20   *   Synchronization Method Two

Each user periodically synchronizes with a well-known and commonly accessible time-keeping source such as the U.S. Naval Observatory. Connect via the Internet or by receiving wireless broadcasts; both methods are well

25   known.

*   Synchronization Method Three

Synchronize using data from the *RDS*. The process will be reasonably obvious to those skilled in the art.

30

Additional Error Correction Procedures

It is critical that the *RDS* broadcasts have an extremely low error rate if the users contemplate

5 utilizing some of the feedback mechanisms outlined above for creating new ks and more secure *RNRs*. With a high data rate, and low error probabilities, the probability that any set of individual users will receive different versions of the *RDS* will be low. Clearly, the

10 consequences of errors will be more significant and destructive in the case of feeding the *SMP* back into *k* to create a new *k*. With high data rates, this will likely create a situation where Bob and Alice possess different ks, and their resulting *SMPs* will not be synchronized.

15 One method for solving this problem without leaking at least some information to a capable adversary is to exchange a new private key. Other techniques may utilize public discussion; hold some private key in reserve for purposes of authentication and error correction. In

20 addition, the system may discuss error correction problems in public, with authentication, without substantially giving away information to potential adversary.

If either the sending or receiving system loses the

25 *RDS*, or obtains the *RDS* and finds an error rate higher than the level indicated by agreement between the parties or embedded in software, the individual user's system will record the amount of time that the *RDS* was unavailable. The user will immediately broadcast or post

30 the times to all users with whom the user exchanges encrypted communications that the *RDS* was not received. A public posting, such as on a Web site, would indicate

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only when the user did not receive the *RDS*, and would not reveal which specific reservoirs were affected, thus preventing a potential adversary from drawing information on when the user's system was attempting to download

5 samples for a specific reservoir. In an alternative embodiment, the system could determine which reservoirs were affected by this broadcast outage and may send encrypted error-alert warnings to the appropriate parties. But, in general, the system should *not*

10 calculate which individual users were affected, and which were not, and then send the information only to those who were affected.

This identification of problem times will allow sets of users to suspend their *RDS* sampling, or perhaps

15 reconstruct an error-propagated *RNR*. The other users will discard the data obtained during the time that the *RDS* was unavailable to the other user. Depending on the algorithms used to construct the reservoir, recalculation of the reservoir may be required to resynchronize.

20 Where a high probability of errors is expected, random data may be held in a separate cache before being added to the official random number reservoir. Alternatively, this cache may hold the numbers inserted into the reservoir. This cache will be triggered for

25 release or cleared after the two users have synchronized their systems again. This process may be automatic.

Still further, a "Spare private keys *k*" may be held in reserve for use when error propagation requires the *RNR* to be reset. These types of reserves must be used

30 carefully, and only when the identity of the other party can be verified. Otherwise the system will be vulnerable to adversaries masquerading as friends who intentionally

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trigger a diversion into the error subroutine. Such an adversary would still need to brute force the reserve key, but at least it will have identified the time at which that private key came into operation.

5

RNR Reservoir Management

*   RNR Reservoir Size

In general, the communications volume and security needs of the individuals exchanging encrypted communications with this system will determine the ideal "size" for the reservoir RNR. "Size" indicates how many bits are stored for ultimate end use as an encrypting key E.

This size, if it is derived from the private key k, and remains secret, may add security against adversaries who attempt to reconstruct the *RNR*. It will have no added security against a brute force attack on the initial private key k.

It is important that the parties utilizing the present invention make a reasonably accurate projection of their communications needs over some unit of time. If this estimate is inaccurate, or communications needs change, another private key transfer may convey this information. Alternatively, this information may be transferred using this encryption system with a minimum of risk.

*   Adding Successive Samples (*SMP*) to the Reservoir (*RNR*)

The secrecy of the reservoir size may be further utilized by using a variety of techniques to integrate successive samples of the *RDS* into the existing reservoir

of random bits so that the initial state and size of the *RNR* will influence future random numbers stored in the *RNR*. In other words, the *RNR* may be constructed from successive *SMP* so that an enemy would need the initial

5 size of the reservoir, and all successive samples in order to reconstruct the random file in the reservoir at any given point in time.

Adding Overall Security

10

Further secrecy may be added using the simple additional methods described here. As indicated above, some or all of the bits from the sample, *SMP*, may be integrated into both the *RNR* and the original private key

15 *k*, to form a new random key, *k*. The new random key k may be used as a new input into z, and, using the above methods, will generate a new time *t*, and a new sample *SMP*.

Those skilled in the art will recognize that is not

20 necessary to integrate every *SMP* into the *RNR*. Instead, in certain embodiments it may be advantageous if the new *SMP* is only used to generate a new *k*, and the value is not integrated into the *RNR*. This process may be repeated many times (iterations). At the end of a

25 predetermined number of iterations, a sample, *SMP*, will be diverted for use in the *RNR*.

Those skilled in the art will recognize there are many methods for integrating some random bits from *SMP*, back into *k* to create a new key. The bits from *SMP* may

30 directly replace the same number of bits in k; s may be XORed with an equivalent number of bits; s may be XORs with same-sized blocks pulled from *k* so that each bit in

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k is XORed with the *SMP*. All these different processes are contemplated for incorporation with this cryptosystem.

5   In practical implementation, users will want to consider an enemy's capabilities and their own communications requirements before defining a size for *k*. In general, those with a high volume of messages per unit time will probably prefer to add computational complexity through repeated iterations, a sophisticated *z*, or a very

10   long original *k*

Alternative Sampling Method (Monitoring method)

The private key *k* is transferred via secure courier,

15   again preferably with no revelation to a potential adversary of the time of the exchange, and entered into the computer system. Each user's User Computer System 108n switches on and constantly monitors the incoming *RDS* for a string of random bits that precisely matches *k*. A

20   sample *SMP* of *s* bits in length is taken after the last bit representing the key appears in the *RDS*. If $s < k$, then *s* will appear more frequently than k, resulting in a hash-type function, where long strings of bits of random length are reduced by a random process to a smaller,

25   fixed length block of bits. This function could provide a hash-type function with a low probability of collision and, for memory bounded adversaries, a very strong one-way function that is computationally infeasible to reverse. As in the above method, some of the bits from

30   *SMP* may be integrated with *k* to form a new *k*, and the process repeated. Multiple iterations are possible, resulting in substantial computational security.

This method has the disadvantage in that it demands more processing than the other embodiment. The *RDS* must be constantly monitored and analyzed, so fast processors are required. But there are several advantages. One is

5   that the enemy must have considerable processing power. A brute force attack on *k* is probably the best attack, and that may require a considerable amount of time and processing power, especially if the time of the key exchange is uncertain. Even enemies with a considerable

10   amount of plaintext will face considerable difficulty attacking this embodiment.

     This method may also be used to validate a message, and insure that it has not been modified during its transmission through the public network. For example,

15   returning to the above-described example of Alice and Bob, assume that Alice sends Bob an encrypted message, which Bob decrypts as described above. Bob's system and software segments the string of bits representing Bob's message into several distinct parts. These segments are

20   then used as disclosed immediately above. Alice's system also breaks the original plaintext message into the exact same segments, using the same basic software and process. Alice and Bob then monitor the incoming RDS on a continuous basis, searching for an identical string of

25   random bits that exactly matches the string of bits in the segments of plaintext. When a match is found, the both systems note and record the string of random bits immediately following the selected segment. Bob (the message recipient) then sends this string of random

30   numbers (or series of numbers, one for each segment) to Alice. (This message may be encrypted.) Alice compares

Bob's series of numbers with her series, and if they are the same, the message's contents can be validated.

Communication Between Individuals
Without a Common Private Key

The present invention contemplates secure communication between two individuals who have not exchanged a private key k, by their utilizing two or more trusted intermediaries, or trusted agents, whom both users have in common. The trusted agents will enable the users to create and exchange a new private key known only to the two individuals. This private key may be used in the system and methods described above to create synchronized RNRs for use in conducting secure communications. Referring to Fig. 4, an example operation is as follows:

At step 400 Alice identifies the intended contact as Bob. Next, at step 402 Alice checks if an RNR exists for Bob. If the answer is "Yes" the process goes to step 404 to encrypt and send the message using, for example, the method described in reference to Fig. 3. If step 402 determines that no RNR exists for Bob, i.e., Alice and Alice have not exchanged a private key, the process goes to step 406. Step 406 operates as follows: Alice and Bob each maintain reservoirs RNR synchronized with two trusted agents, whom they have in common, Zeke and Yvonne. That is, Bob has exchanged separate private keys with Yvonne and Zeke, and maintains synchronized *RNRs* with each so that Bob may conduct secret communications with Yvonne and Zeke, respectively. Alice has also

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exchanged separate private keys and similarly maintains separate synchronized *RNRs* with Yvonne and Zeke.

In an ideal embodiment, both Bob and Alice will publicly "broadcast" or "post" their trusted agents so
5   that this knowledge is freely available. For example, this information may be posted on an individual's Web site or included in the individual's email address, or posted like a telephone number in a public directory.

Referring to Fig. 4, Alice downloads Bob's list of
10   trusted agents at step 406 and, at step 408 compares the list with Alice's own list of trusted agents. If step 410 determines that Alice and Bob have two trusted agents in common the process goes to step 412 where Alice sends a private key generation request which includes Bob's
15   address to both of the trusted agents, which is described further below. Assuming that the two trusted agents are Yvonne and Zeke, Bob will then use this information to send Alice a private key through Yvonne and Zeke. An enemy will have no idea that Bob has chosen to contact
20   Alice—thus the private key transfer has remained secret in time as well as content. Other forms of exchange are contemplated, but they are not as secure. For example, Bob and Alice may exchange public messages indicating their wish to communicate in private. Even this limited
25   public exchange allows the enemy to narrow the probability of the start time. Perfect secrecy may still be attained, but some entropy has been unnecessarily squandered.

As recited above, at step 412 Alice sends a "key
30   generation request" to both Zeke and Yvonne that includes Bob's identity and address. Other instructions may be included in order to facilitate communications, or to

confuse an adversary.   Using a method described below in reference to Fig. 5, Zeke generates a random number A that he encrypts using the *RNR* he has in common with Bob, and passes the new random number to Bob.   Zeke also sends

5   the same random number A to Alice, as shown in Fig. 4, step 414, using the reservoir he has in common with Alice.   Yvonne undertakes the same Fig. 5 process; creating and sending random number B in an encrypted message to both Alice and Bob.

10   Alternatively, Alice could generate two random numbers and pass one to Zeke as an encrypted message and one to Yvonne as encrypted message. Zeke and Yvonne "open" the message, obtain the random numbers, and then encrypt them using their *RNRs* that they have in common

15   with Bob. They then pass these random numbers to Bob, per Alice's instructions.

     Referring again to Fig. 4, at step 416 Alice and Bob receive the messages from Zeke and Yvonne.   Then, at step 418 a new secrecy key is generated by Bob and Alice by

20   each XORing the two random numbers A and B to create a third number, C.   This is the new private key, which is then used at step 420 in the manner disclosed above in reference to Fig. 3.

     The Fig. 4 process described above is for the

25   example when Alice's step 412 determines that Alice and Bob share two trusted agents in common.   If step 412 does not determine two trusted agents in common the process goes to step 422 where Alice selects two of her trusted agents. Then, the process goes to step 424, which is the

30   process shown at step 200 of Fig. 3 for creating and exchanging a private key *k* when contact (Bob in this

example) does not share trusted agents with the sender (Alice).

As long as Zeke and Yvonne do not collude, Bob and Alice may exchange perfectly secure communications.

5   Further security against collusion may be obtained by increasing the number of agents. Each agent will be used to transfer a separate random number to the desired party. Each random number will be required to form the final private key, created by XORing each private key in

10   turn. Increasing the number of agents to more than two makes it more and more difficult to coordinate collusion, yet unanimous participation is required for an adversary to gain information on the private key.

For certain embodiments, it would be advantageous to

15   create a network of trusted agents that have a minimum of memory, or memory that automatically expires, so that the trusted agent retains no record of the random number it created for Bob and Alice. If the trusted agent retains no record, future leakage of all information on its *RNRs*

20   will not reveal the private keys exchanged by Bob and Alice. Such memoryless servers would be ideal for facilitating communications on a public network, or where there may be high penalties for a compromised agent.

Figure 5 describes one possible method for utilizing

25   two trusted intermediaries to exchange a secure private key, as viewed from the perspective of the trusted intermediary (or "agent"). The process starts when the trusted agent receives a message from Alice (500). (This process should be identical both of the trusted agents

30   involved in this process of exchanging a secure private key.) The agent will quickly determined if this message is encrypted (502), and if it is, will decrypt (502)

using the appropriate *RNR* for Alice. It is preferable for Alice to encrypt the message to the trusted agent in order to reduce the information a potential adversary may have regarding the time of the private key exchange

5 between Alice and Bob. Whether or not the original message is encrypted, the message will reveal that Bob is target contact (506). The trusted agent will search its records to evaluate whether or not it has an ongoing *RNR* in common with Bob (508). (It has exchanged a private key

10 in the past and formed a trusted relationship.) If there is no common *RNR* with Bob, the trusted agent can undertake a process to determine if it has two other trusted intermediaries in common with Bob (510, and see Figure 6). Although Bob and the trusted agent do not

15 have an established private key, they may in turn have exchanged private keys with two other trusted agents whom they both have in common. (Thus the trusted agent in this process now acts like Bob and Alice, who do not have a trusted agent in common.) If Bob and the trusted agent

20 do indeed have an *RNR* in common (the trusted agent for Alice is also a trusted agent for Bob), then the agent will generate a new random number, in most cases using the RDS (512). This random number will then be encrypted using Alice's *RNR* (514) and sent to Alice (516). The

25 same random number will also be encrypted using Bob's *RNR* (518) and sent to Bob (520). Alice and Bob will each decrypt this message from the trusted agent revealing the trusted agent's random number; this process will be repeated for the other trusted agent. Then Bob and Alice

30 will XOR the two random numbers to obtain a new and

unique random number that may function as a secure
private key. (See Figure 9.)

Figure 6 represents the basic subroutine that the
trusted agent may take when it encounters the situation

5   in Figure 5 (510) where it is handling a random key
generation request from Alice, but has no *RNR* in common
with Bob. The objective is to create a private key and
subsequent *RNR* between the trusted agent and Bob so that
the agent may then, in turn, provide the trusted agent

10   service described in Figure 5 for Alice. If this trusted
agent does not have two trusted agents in common with
Bob, it will seek out other trusted agents who may have
the necessary secure *RNRs* in common with Bob. (604, and
also see Figure 8 for a broader overview). If the

15   trusted agent does indeed find two other trusted agents
it has in common with Bob, it will use these agents to
create a secure private key it has in common with Bob
(see Figure 5) and will then form a new *RNR* in common
with Bob (608). Processes 610 and 612 represent the

20   trusted agents efforts to complete the transaction
requested by Alice—these last steps replicate the actions
taken in Figure 5. Together, Figures 5, 6, and 8
represent how the same basic processes may be repeated so
that individuals who have never met may utilize a network

25   of trusted agents to exchange a secure private key that
will form the foundation for a secure *RNR*. As long as
this network of trusted agents does not collude or
disclose other information about the messages it has
exchanged with Bob and Alice (or other users with whom

30   the trusted agents has formed ongoing *RNRs*) then the

encryption system will be able to allow individuals who
have never met to exchange secure private keys through a
public network. Those skilled in the art will quickly
appreciate that users need not confine themselves to

5   using two trusted intermediaries to exchange a secure
private key; there are advantages to increasing the
number of trusted intermediaries. As the number
increases, an adversary will need to successfully attack
each trusted intermediary in order to obtain information

10 about the private key exchanged by Bob and Alice. This
large network of trusted agents thus reduces the "fat
target" problem, where a single trusted intermediary
represents an ideal target for an adversary because it
contains information on multiple keys and individual

15 users.

Figure 7 describes an alternative process for using
two trusted agents to create and transfer a secure
private key between two individuals, Alice and Bob, who
have never met or exchanged a private key but do have two

20 trusted agents in common. To start to the process, Alice
will contact Bob through a public channel (700),
indicating that she wants to develop a secure private key
in common with Bob so that they may conduct secure
private communications. In this public discussion,

25 represented by 702, the two users will exchange
information about their trusted agents and will identify
two that they both have in common. Alice will then
generate two random numbers (706), one for Zeke (Z1), and
one for Yvonne (Y1). Z1 will be encrypted using the *RNR*

30 for Zeke(708) and the encrypted message will be sent to

53

Zeke (710); Y1 will be encrypted using the *RNR* in common

with Yvonne (720), and the resulting encrypted message

sent to Yvonne (722). Both Zeke and Yvonne will decrypt

the encrypted message (712 and 724, respectively),

5   revealing the random numbers. (Zeke will now know Z1,

and Yvonne knows Y1.) Zeke will now encrypt Z1 using an

RNR he has in common with Bob (714), and will send the

resulting encrypted message to Bob (716). Yvonne will

encrypt Y1 using the *RNR* she has in common with Bob

10   (726), and will send the resulting encrypted message to

Bob (728). Bob will decrypt Zeke's incoming encrypted

message using his Zeke *RNR* to reveal Z1 (718); Bob will

also decrypt Yvonne's incoming encrypted message to

reveal Y1 (730). Now Bob will XOR Z1 and Y1 to create a

15   new random number; Alice will also XOR Z1 and Y1 to

create the exact same private key, K. (740) The advantage

of this method is that as long as Zeke and Yvonne do not

collude, neither will be able to obtain the ultimate

private key, K, created from the XOR of Z1 with Y1.

20   In an alternative embodiment, information on trusted

intermediaries may be publicly posted, such as on a Web

site. In this scenario, Alice may scan Bob's Web site,

and identify two trusted intermediaries that she has

common with Bob without Bob's knowledge. Alice will then

25   use the above process to transfer a private key to Bob.

Bob will not know that the incoming communications from

his trusted agents Zeke and Yvonne carries a random

number that is to be used to construct a secure private

key in common with Alice, but he may easily informed by

30   both Zeke and Yvonne of the purpose of this particular

secret communication. The objective and end result is to again create uncertainty for an adversary regarding the time of the private key exchanged between Alice and Bob. Unless the adversary has logged all visitors to Bob's Web

5   site, the adversary will be unable to identify precisely when Alice sent Bob a private key.

Figure 8 incorporates the processes described in Figures 5 and 6 to provide an "overview" of how successive layers of trusted agents may network together

10   to deliver secure private keys to two individuals (Bob and Alice) who have never met. In step 800, Bob and Alice discover only one trusted agent in common, so Alice sends a key generation request to Yvonne (802) (whom is common to Alice and Bob) and also to Zeke, who has a

15   trusted *RNR* in common with Alice but not Bob. Yvonne follows the process explained in Figure 5 (822 and 824). Zeke's process (804-820) is another representation of the process described for Figure 6. Zeke and Bob both try to find common trusted agents (804 and 806) and use these

20   agents (808, 810, and 812) to first generate a secure private key (814) with Bob and a secure *RNR*. When this is completed (820) Zeke will now have *RNRs* in common with both Bob and Alice, allowing Zeke to fulfill the private key generation request from Alice (818). Again, those

25   skilled in the art will appreciate that this is a representation how a network of trusted agents can communicate through public channels and use the same basic processes to allow users who have never met to exchange private keys. With enough time, the repetition

30   of this process will eventually create a large network of

trusted agents and users who may facilitate the exchange
of private keys through a public network—without
requiring the use of an expensive trusted courier.
Instead, the network of trusted agents has replaced the

5   courier, thus allowing decreases in cost, and
potentially, substantial increases in the speed of
private key exchanges.

The advantages of these methods are substantial. In
a networked environment, such as the public Internet, it

10   is possible that any individual user would need to use a
trusted courier or other equally secure means of
exchanging a private key only twice to create two trusted
agents. If these trusted agents have exchanged private
keys with two other trusted agents, and so on, then any

15   individual user could then utilize the network of trusted
agents to create and exchange a private key with any
other individual user over the public Internet. This is
a considerable advantage over the current art of private
key cryptography, because it substantially reduces the

20   key management problem related to constantly utilizing
expensive couriers to transfer private keys. In a
networked environment with a sufficient number of trusted
agents, or a few trusted agents with many connections to
users, any individual user would need to use a trusted

25   courier only twice, to establish secure keys with two
separate trusted agents. All other private keys with all
other users could be developed through secure
communications with the two trusted agents over the
public network. It is also an advance over public key

30   systems in the sense that after absorbing the initial
cost of conducting a secure key exchange with two trusted
agents, the cost and complexity of using the present

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invention in a network will be substantially less in time and cost (and greater in security) than a public key system implemented to achieve similar applications and transactions.

5   In many applications, such as in using this system and methods to conduct financial transactions, the use of two trusted agents may be used to introduce a measure of anonymity in a purchase, either with the seller, or the financial institution, or both.

10   The use of the trusted agents in this system has the further advantage that neither trusted agent will be able to identify the value of the newly created private key k unless the two trusted agents collude. This collusion is unlikely in a commercial setting because presumably the

15   trusted agent would generate revenue based on its trustworthiness, that is, its expressed statement that it will never collude.

Yet it is an advantage of the present invention that law enforcement officials possessing proper and valid

20   search warrants may request the random number provided by each trusted agent to each user, and then use these numbers to recreate the private key, k. The law enforcement organization may then be able to recreate the *RNRs* and encrypted communications of the two users, but

25   only if the law enforcement organization has a substantial portion of the *RDS* for the time period covered by the private key k. Furthermore, it is an advantage that the search warrant can be very specific: the law enforcement organization will recreate the

30   private key and subsequent communications only for the communications between two specific users. The other communications between any one user and his or her other

contacts will not be accessible. This is a substantial advantage over public key systems where revelation of a user's public key through a search warrant would enable the law enforcement agency to examine all the user's

5   incoming communications, not just the targeted communications between the two users.

Financial Transactions

10   Those skilled in the art will readily appreciate that this system and methods may be applied to create secure electronic financial transactions. One process, though not the only one, enables a buyer, Bob, to purchase from a seller, Alice, without ever revealing the

15   actual credit card number or account information to Alice. More specifically, assume that Bob is making an electronic purchase over the Internet using a credit card accepted by Alice. Both Bob and Alice have exchanged private keys with a trusted agent they both have in

20   common, perhaps a financial institution such as a credit card company.

To utilize this system to exchange payment and credit card information, Bob obtains the price of the goods he wishes to purchase, plus other unique

25   information identifying Alice (such as a bank routing number for payment), if necessary. Bob places this information and his credit card number inside a message in a predetermined format so that it may be quickly processed by the trusted agent. Bob encrypts this

30   message with the *RNR* he has in common with the credit card company and the trusted agent. He may then pass the encrypted message directly to the trusted agent or back

to Alice. If Bob passes the message to the credit card company, the credit card company decrypts the message to obtain Bob's credit card number, the amount Bob wishes to withdraw or charge, and the destination of the funds.

5 The credit card company may now pass this information to and confirm the transaction with Alice, using the *RNR* shared by the company and Alice. The hash-type function described in the "Alternative Methods" section above may be used to validate and "sign" all the messages.

10 Many other methods are contemplated using this system and its methods to implement secure financial transactions. For example, trusted agents with large numbers of "clients" (customers with whom the agent has exchanged private keys and maintains an *RNR*) may rapidly

15 create a type of currency from issuing random numbers that represent specified amounts of currency, securities, or other elements traditionally used to represent or hold value in a financial transaction.

Two trusted intermediaries may be used to generate

20 some anonymity in transactions. Assume, for example, two common trusted intermediaries, Zeke and Yvonne, and a buyer and seller, Bob and Alice, who have exchanged private keys and enjoy secure communications with each party. Bob generates a random number, encrypts it using

25 Alice's *RNR*, and sends it to Alice. Bob then sends this same random number, encrypted, to Zeke, plus payment information—but Alice's name is not included in the information. The random number generated by Bob for Alice and Zeke will substitute for Alice's name. Alice sends

30 this same random number (encrypted) to Yvonne, plus information on Zeke so that Yvonne may quickly identify with whom she should communicate. Assuming that Yvonne

already enjoys secure communications with Zeke, she may now present the random number to Zeke, who then transfers the appropriate value requested by Bob to Yvonne. Yvonne, of course, then transfers this value to Alice's

5   account, and confirms the transaction for Alice. The use of two trusted intermediaries and blind random numbers inserts an extra layer in a normal financial transaction to obtain some limited anonymity without losing any security or ability to prevent copying or repudiation.

10   Zeke does not know whom Bob is paying; Yvonne does not know from whom Alice is receiving payment.

Those skilled in the art will readily appreciate these techniques, and will conceive of many others using the basic principles disclosed above for the operation of

15   the present invention's system and methods. The main advantages of financial transactions conducted with the present invention over the prior art of encryption (public and private key) are that the present invention conducts transactions that are faster, more secure, and

20   lower in cost. This combination of speed, security, and cost enables users and trusted agents of this system and methods to rapidly and inexpensively conduct many sub-transactions and exchanges of information without incurring a security risk. Layering transactions enables

25   the creation of buffers that provide anonymity; multiple sub-transactions allows trusted agents to rapidly transfer value across a diverse public network, enabling widespread electronic commerce between users and other institutions who have never met. Other systems based on

30   the prior art of encryption could not conduct multiple layers of transactions without imposing very high costs and long wait times upon the buyers and sellers.

Authentication with two trusted intermediaries

One critical advantage of this system is that the
5 exchange of private keys, *k*, also provides an inherent
mechanism for identifying and authenticating the identity
of the other party to the satisfaction of both users. The
process of exchanging the private key also becomes the
point in time at which each user authenticates the
10 identity of the other user. Future encrypted messages
exchanged between these two users are thus inherently
authenticated with a very low risk that an adversary has
substituted a false message.

While the foregoing invention has been described
15 with specific references to examples of its preferred
embodiments, it should be understood that various
substitutions, variations, and modifications may be made
thereto without departing from the scope of the invention
as defined in the appended claims.

CLAIMS

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

1 1.   A method for encrypting and decrypting data
2 comprising steps of:
3   generating a random number sequence;
4   transmitting the random number sequence to a data
5 encryption station and a data decryption station;
6   generating a private key;
7   inputting the private key to the data encryption
8 station and to the data decryption station;
9   selecting at the data encryption station an
10 encryption subsequence from the random number sequence,
11 the boundaries of the encryption subsequence based on the
12 private key;
13   encrypting a plaintext data at the data encryption
14 station based on the private key and the selected
15 encryption subsequence and generating, as a result, an
16 encrypted data;
17   transmitting the encrypted data from the encryption
18 station to the decryption station;
19   selecting at the data decryption station, based on
20 the private key input to the decryption station, a
21 decryption subsequence from the random number sequence,
22 the boundaries of the decryption subsequence being
23 identical to the boundaries of the encryption
24 subsequence; and

25   decrypting the encrypted data at the data decryption
26 station based on the private key and selection decryption
27 sequence and generating, as a result, a recovered
28 plaintext data.

1   2.   A method according to claim 1 further comprising
2 steps of
3   generating a synchronization signal;
4   generating, at the encryption station, a first
5 sampling time t based on the input private key;
6   sampling the random number sequence at the
7 encryption station for a predetermined interval beginning
8 at a time based on t, to generate a sampled block of
9 bits; and
10   storing the sampled block of bits in a random number
11 reservoir,
12   wherein said encrypting step is based, in part, on a
13 content of said random number reservoir.

1   3.   A method according to claim 1, further comprising
2 steps of:
3   generating a synchronization signal;
4   generating, at the encryption station, a sampling
5 time t based on the input private key;
6   sampling the random number sequence at the
7 encryption station for a predetermined interval beginning
8 at a time based on t, to generate a sampled block of
9 bits;
10   detecting a number of bits in said random number
11 reservoir;

12   comparing the number of bits detected by said
13 detecting step with a predetermined reservoir full value;
14 and

15   based on said comparing step detecting the number of
16 bits in said random number reservoir being less than said
17 predetermined reservoir full value, performing a step of
18 storing the sampled block of bits in a random number
19 reservoir,

20   wherein said encrypting step is based, in part, on a
21 content of said random number reservoir

1   4. A method according to claim 3 further comprising
2   steps of:

3   based on said comparing step detecting the number of
4   bits in said random number reservoir being less than said
5   predetermined reservoir full value, performing steps of:

6   (a) generating a new private key based on the
7   sampled block of bits and the previous private key;

8   (b) generating a new sampling time t based, at
9   least in part, on the new private key;

10   (c) sampling an additional block of bits from the
11 random number sequence, at a sampling time based on the
12 new sampling time t;

13   (d) detecting a number of bits in said random
14 number reservoir;

15   (e) comparing the number of bits detected by said
16 detecting step with a predetermined reservoir full value;

17   (f) based on said comparing step detecting the
18 number of bits in said random number reservoir being less
19 than said predetermined reservoir full value, performing

20 a step of storing the sampled additional block of bits in
21 said random number reservoir; and
22   (g) repeating steps (a) through (f) until said
23 comparing step detects the number of bits in said random
24 number reservoir as being greater than or equal to said
25 predetermined reservoir full value.

1 5.   A method according to claim 1 wherein said step of
2 transmitting the random number sequence includes steps
3 of:
4   transmitting said random number sequence by uplink
5 up to a satellite;
6   transmitting said random number sequence received by
7 said satellite down to said encryption station and to
8 said decryption station.

GLOBAL ENCRYPTION SYSTEM

ABSTRACT OF THE DISCLOSURE

A system and method for encryption, transmission and decryption of data based on a publicly or other wide area broadcast random number sequence. Encryption is by a selected subsequence from the broadcast random number sequence, the selection being at a sample time relative to a synchronization event, with the sample time calculated based on a private key. Decryption uses the same private key to select the same subsequence from the broadcast random number sequence, as detection by the sender and receiver of the synchronization event and a sampling time based on a commonly known private key allows the sampling to be synchronous. Alternative embodiments employ trusted agents if the sender and receiver do not have a common private key.

FIGURE 1

1010

Keyboard or other
Manual Input Device

1014

Removable Data Storage

1016

Satellite Receiver or Fiber Optic Line

Common Bus

Modem

1018

Long-term Data Storage

Microprocessor

RAM

Clock

ROM

1000

1004

1006

1008

1012

1002

Fig. 2

200 Exchange private keys, *k*

202 Input *k* into Function (z) to generate time *t*

204 Check clock

208 Wait State

206 Does the *t* match the clock?

210 Begin receiving RDS broadcast

212 Reconstruct RDS

214 Select exact *SMP* for *t*

216 XOR *SMP* into *k* to create *k1*

218 Check counter

220 Counter equal to value in software or determined by *k*?

222 Advance counter

224 XOR *SMP* with existing bits in *RNR-*

226 Is the *RNR* full?

228 Add *SMP* bits to the RNR

230 Discard *SMP*

240 Create plaintext, *P*

242 Does *RNR* exist for target contact?

244 Count the number of bits in *p*

246 Count the number of bits in the *RNR*

250 Wait State

248 *RNR* bits>=*p* bits?

252 Extract equal number of bits from *RNR*

254 XOR *RNR* bits with *p* to create cipher text *c*

256 Send *C* to target contact

258 Discard bits extracted from the *RNR*

Receive ciphertext *c*

262 Does *RNR* exist for target contact?

264 Count the number of bits in *c*

266 Extract equal number of bits from *RNR*

268 XOR *RNR* bits with *c* to recreate plain text *p*

270 Discard bits extracted from the *RNR*

No / Yes

Diagram One- Basic Operation

FIGURE 3

FIGURE 4

Figure 5
Trusted Agent
Handling Private Key Generation Request

500 —

Receive request
from Alice

502 — Encrypted?

Yes

504 — Decrypt to acquire
message

No

506 — Identify target
contact, Bob

508 — Is there an RNR for
Bob?

No — See Figure 6 for
developing common
private key with Bob

510

Yes

512 — Generate Random
Number (from
RDS)

516

514 — Encrypt random
number using
Alice's RNR

Send encrypted
random number to
Alice

518 — Encrypt random
number using RNR
of target contact
(Bob)

Send encrypted
random number to
target contact (Bob) — 520

Figure 6
Trusted Agent

Seek common parties to allow communication between individuals who
do not share two trusted third parties
Trusted agent repeats Private key generation request process with two
or more trusted agents it has in common with Bob

Identify target contact, Bob —600

Two trusted agents in Common? 602

—No→ See Overall Process for handling unshared trusted agents (Figure 8) 604

Yes

Follow Private Key Generation Process (Figure 5) 606

Use new private key to generate *RNR* for Bob 608

Generate random number 610

Follow trusted agent generation procedure to complete transaction 612

Figure 7

ternative method for using two trusted agents to create a secure private key for a new contact

```
                                          ┌─────────────────────┐
                                          │ Alice opens public  │
                                          │   communications    │
                                          │      with Bob       │
                                          │        700          │
                                          └─────────────────────┘
                                                     │
                                                     ▼
                                          ┌─────────────────────┐
                                          │   Identify 2 or more │
                                          │   trusted agents in  │
                                          │  common, Zeke and    │
                                          │       Yvonne         │
                                          │        702           │
                                          └─────────────────────┘
                                                     │
                                                     ▼
                                          ┌─────────────────────┐
                                          │   Generate one       │
                                          │  random number for   │
                                          │  each trusted agent  │
                                          │      (Z1,Y1)         │
                                          │        706           │
                                          └─────────────────────┘
                                                     │
                                                     ▼
┌──────────────────┐                      ┌─────────────────────┐
│ Send encrypted Z1│◀─────────────────────│   Encrypt Z1 using   │
│    to Zeke       │                      │    RNR for Zeke      │
│      710         │                      │        708           │
└──────────────────┘                      └─────────────────────┘
         │                                           │
         ▼                                           ▼
┌──────────────────┐          ┌─────────────────────┐          ┌──────────────────┐
│ Zeke decrypts to │          │   Encrypt Y1 with    │─────────▶│ Send encrypted Y1│
│   reveal Z1      │          │    RNR for Yvonne     │          │    to Yvonne     │
│      712         │          │        720            │          │      722         │
└──────────────────┘          └─────────────────────┘          └──────────────────┘
         │                                │                               │
         ▼                                │                               ▼
┌──────────────────┐                      │                     ┌──────────────────┐
│  Zeke uses RNR in│                      │                     │ Yvonne decrypts to│
│  common with Bob │                      │                     │    reveal Y1     │
│  to encrypt Z1   │                      │                     │      724         │
│      714         │                      │                     └──────────────────┘
└──────────────────┘                      │                               │
         │                                │                               ▼
         ▼                                │                     ┌──────────────────┐
┌──────────────────┐                      │                     │ Yvonne uses RNR  │
│   Zeke sends     │                      │                     │ in common with   │
│ encrypted message│                      │                     │ Bob to encrypt Y1│
│    to Bob        │                      │                     │      726         │
│      716         │                      │                     └──────────────────┘
└──────────────────┘                      │                               │
         │                                │                               ▼
         ▼                                │                     ┌──────────────────┐
┌──────────────────┐                      │                     │  Yvonne sends    │
│ Bob receives     │                      ▼                     │ encrypted message│
│ message from Zeke│          ┌─────────────────────┐           │    to Bob        │
│ and decrypts to  │─────────▶│  Bob and Alice XOR   │◀──────────│      728         │
│   obtain Z1      │          │  Z1 and Y1 to create │           └──────────────────┘
│      718         │          │   new private key K  │                     │
└──────────────────┘          │        740           │                     ▼
                              └─────────────────────┘           ┌──────────────────┐
                                                                │  Bob receives    │
                                                                │  message from    │
                                                                │  Yvonne and      │
                                                                │ decrypts to obtain│
                                                                │       Y1         │
                                                                │      730         │
                                                                └──────────────────┘
```

Process One - - - - → Alice and Bob find
                      only one common   ⟍ 800
                      trusted agent

Process Two   Overall Process for generating
                                               a private key when there is
                                               only one trusted agent in
    Process Three   common

                      Alice sends key   ⟍ 802   Process Five
                      generation request
                      to two of her trusted
                      agents

Trusted Agent Zeke   Process Four
seeks two trusted
agents it has in   ⟍ 804
common with Bob

                                                            Trusted Agent Zeke   ⟍ 820   Trusted Agent
Discover common   ⟍ 806   now common to   Yvonne   ⟍ 822
trusted agents   Bob and Alice   Common to Bob
Charlie and Dave   and Alice

                          Zeke and Bob now
                          have private key
Zeke sends key   ⟍ 808   and RNR in
generation request   common
to Charlie and Dave
                                                            Zeke fills key   Yvonne fills key
                                                            generation request   generation request
        ⟍ 810   ⟍ 812

Charlie fills key   Dave fills key   ⟍ 818   ⟍ 824
generation request   generation request

                                            ⟍ 814
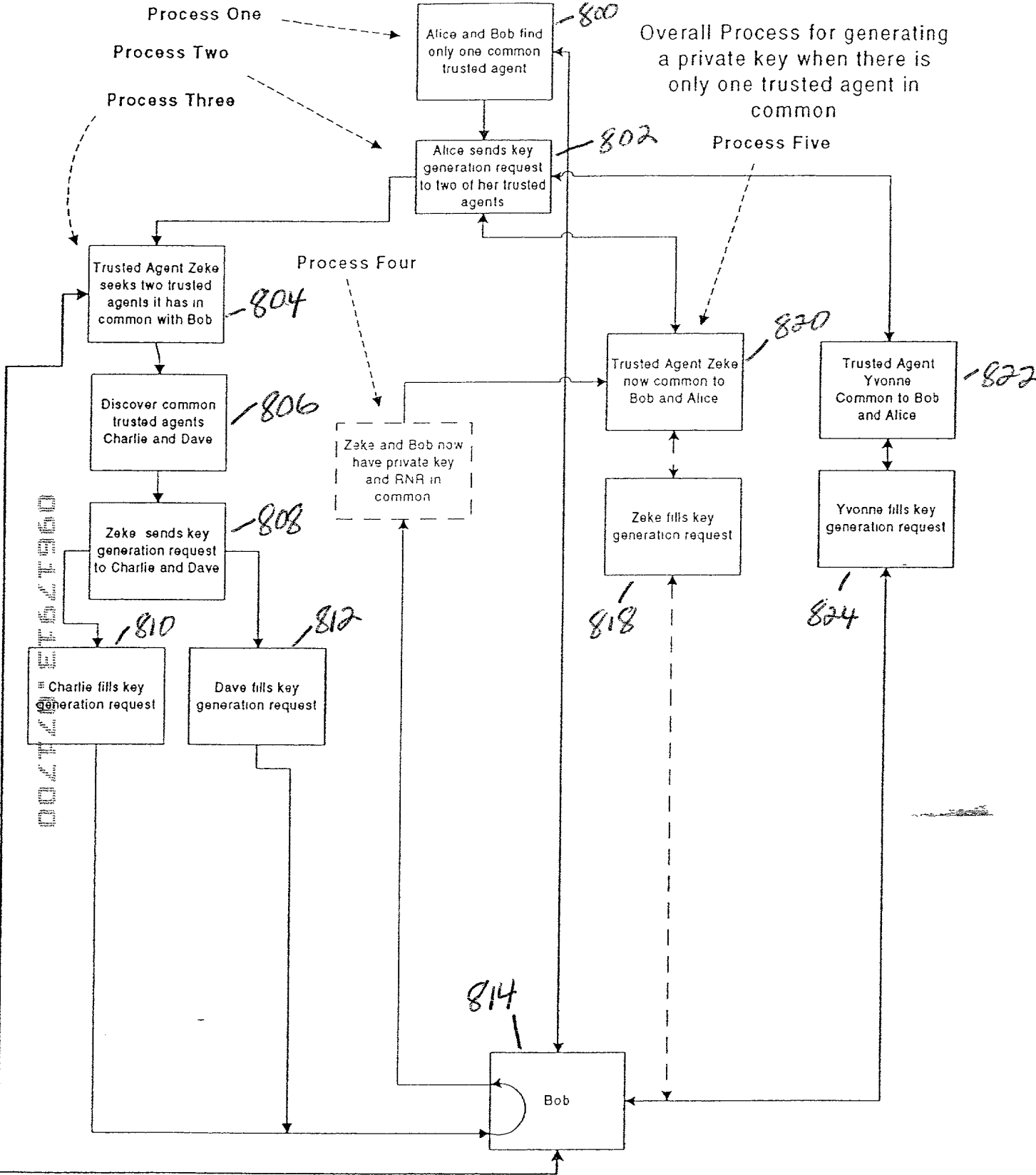
                                   Bob
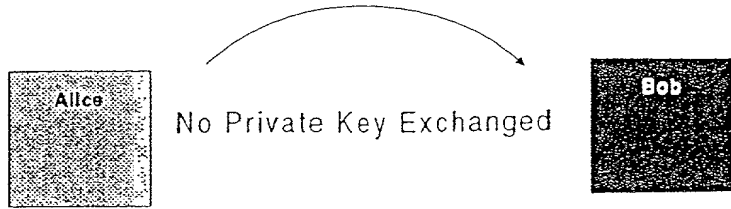
FIGURE 8

FIGURE 9

But Alice and Bob have secure communications with
third-party agents who they have in common

Alice and Bob
XOR
A and B
to create a new private key
C

Zed knows A but not B
Yvonne knows B but not A
To obtain C they must
collude